

Energy, Efficiency and Sustainability: Carbon Footprint Reduction in Industry through the Implementation of the ISO 50001 Standard

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It determines that the implementation of ISO 50001 in industrial companies and projects its impact on sustainability through an approach based on data and studies in industrial companies, demonstrating how the standard can improve energy efficiency and reduce CO₂ emissions, contributing to the Sustainable Development Goals (SDGs). It seeks to demonstrate the feasibility and benefits of integrating energy management practices to achieve sustainability goals. Case studies were conducted in various industries that have implemented ISO 50001. Quantitative methods were used to measure CO₂ emission reductions and energy efficiency improvements. Data were collected through energy audits, sustainability reports and interviews with energy managers. The results indicate that the implementation of ISO 50001 has led to an average reduction of 10-20 % in CO₂ emissions. A significant improvement in energy efficiency was observed, with a reduction in energy consumption of up to 15 %. ISO 50001 is an effective tool for the reduction of the carbon footprint in industry, its implementation not only improves energy efficiency, but also contributes to the environmental and economic sustainability of companies.

1. Introduction

Growing concerns about climate change and sustainability have led industries to look for ways to reduce their carbon footprint (Acha et al., 2021). Energy efficiency and sustainability (Cansino, 2020), have become key pillars for achieving the Sustainable Development Goals (SDGs, 2015). This article explores the interrelationships between energy, efficiency and sustainability (Carpintero and Frechoso, 2023), and how the implementation of energy management practices can contribute to reducing CO₂ emissions and improving industrial sustainability (ISO 14083, 2023). Energy is an essential resource for the operation of industries (Torres and Lituma, 2023). However, inefficient energy use can lead to an unnecessary increase in greenhouse gas emissions (ISO 14064-1, 2018). Energy efficiency refers to the ability to use less energy to perform the same task, which not only reduces operating costs, but also reduces environmental impact (Cansino, 2020). The implementation of ISO 50001 provides a framework for energy management that helps organizations improve their energy efficiency (ISO 50001, 2018). This standard sets requirements for the implementation, maintenance and improvement of an energy management system (Bernabé et al., 2024), enabling companies to reduce their energy consumption and CO₂ emissions (Finch et al., 2024). Sustainability in the industrial context implies the adoption of practices (Zeebroeck, 2011), which allow meeting present needs without compromising the ability of future generations to meet their own needs (Cardona et al., 2024). This includes efficient resource management, waste reduction and minimization of environmental impact (Hernández, 2023). Carbon footprint is a measure of an organization's environmental impact in terms of the amount of greenhouse gases it emits (ISO 14064-1, 2018). The implementation of energy efficiency practices (Cansino, 2020), such as those

established by ISO 50001 (Birkeland, 2014), can contribute significantly to the reduction of the carbon footprint (Espíndola and Valderrama, 2012).

2. Theoretical framework

2.1 Energy and Energy Efficiency

Energy is a fundamental resource for the operation of industries (Aristizábal and González, 2021), inefficient energy use can lead to an unnecessary increase in greenhouse gas emissions contributing to climate change (Castrillón and González, 2018). Energy efficiency refers to the ability to use less energy to perform the same task (De Laire, 2015), which not only reduces operating costs, but also reduces environmental impact (Konrad, 2015). Improving energy efficiency in industries is crucial to reduce energy consumption and CO₂ emissions (Man et al., 2020), thus contributing to environmental and economic sustainability (Feuillet et al., 2022).

2.2 Sustainability

Sustainability in the industrial context implies the adoption of practices that allow meeting present needs without compromising the ability of future generations, to meet their own needs (Martinez and Terranova, 2021). This includes efficient resource management, waste reduction and minimization of environmental impact (ISO/TC 176/SC 2, 2015). Sustainability has become a key objective for many industries as it not only enhances corporate reputation (LAW 1931, 2018), but can also lead to significant cost savings and the creation of new business opportunities (Finch et al., 2024). The United Nations Resolution 70/1 of 2015, known as the "2030 Agenda", establishes the 17 Sustainable Development Goals (SDGs, 2015), which promote a plan of action to benefit people, planet and prosperity (Paniagua and Durán, 2023).

2.3 Implementation of ISO 50001

It provides a framework for energy management that helps organizations improve their energy efficiency (Cooper, 2015). This standard sets requirements for the implementation (Gopalakrishnan et al., 2014), maintenance and improvement of an energy management system, which enables companies to reduce their energy consumption and CO₂ emissions (Dall'O' et al., 2020). Implementation of ISO 50001 involves conducting energy audits, setting energy objectives and targets, and adopting continuous improvement practices (Smiljanic, 2017). Studies have shown that the adoption of ISO 50001 can lead to a significant reduction in energy consumption and greenhouse gas emissions (Casella et al., 2016). Guiding energy management to optimize consumption in 4 approaches: management, operation, evaluation and review (Fiedler and Mircea, 2012).

2.4 Carbon Footprint Reduction

Carbon footprint is a measure of an organization's environmental impact in terms of the amount of greenhouse gases it emits (Harte and Thickett, 2024). The implementation of energy efficiency practices, such as those established by ISO 50001, can contribute significantly to the reduction of the carbon footprint (Oliveira et al., 2024). Reducing the carbon footprint is not only important for mitigating climate change, but can also improve the competitiveness of companies by reducing operating costs and complying with environmental regulations (Olivera et al., 2013). ISO 14064:2015 establishes guidelines for carbon footprint determination using a Life Cycle Analysis (LCA) approach (Espíndola and Valderrama, 2016), considering the requirements and inventory design of GHG emissions at the organizational level; Quantification, monitoring and reporting on GHG reduction and elimination and validation of information (United Nations, 2018).

3. Methodology

To analyze the impact of ISO 50001 implementation on energy efficiency and sustainability (Fuchs et al., 2018), case studies were carried out in various industries. Quantitative methods were used to measure CO₂ emission reduction (Canciano et al., 2020) and energy efficiency improvement (Colina-Calvo, 2024). Data were collected through energy audits, sustainability reports and interviews with energy managers. The study is based on a quantitative approach to assess the impact of ISO 50001 implementation on energy efficiency and carbon footprint reduction in industry, using statistical methods and power quality analyzer equipment. Performance indicators (KPIs) such as energy consumption per unit of production, tons produced and monthly turnover were calculated. To ensure the validity and reliability of the results, data triangulation was performed, comparing the findings of energy audits, sustainability reports, calibrated and certified equipment.

4. Results

The results demonstrate the feasibility and benefits of integrating energy management practices to achieve sustainability goals. Records of power quality parameters are made for 02 Transformers of 1000 Kva, 10-22.9/046 Kv.

Table 1. Electrical Parameters Analyzed

Installed Power	Active Power-KW	Reactive Power-Kvar	Apparent Power Kva	Power factor PF	Voltage V	Current I	Flicker	THDv %	THDi %	K-Factor
Transformer 1000 Kva 10/0.46 - SSEE 1	519.20	239.0	576.88	0.90	440.00	757.00	1.200	4.2	15.7	1.90
Transformer 1000 Kva 22.9 -10/0.46- SSEE 2	383.00	215.00	454.00	0.84	440.00	595.00	2.60	5.01	30	4.35
Total	902.20		1,030.88			1,352.00				

In Table 1, data on low power factor and harmonic distortion (THDi) are recorded. During the 2024 energy audit, an average monthly consumption of 343,832 kWh was observed: 13,649 kWh were recorded due to low power factor; 11,139 kWh of consumption attributable to harmonic distortion and oversized equipment were identified. Another 10,245 kWh were recorded as energy losses.

The Active Power, during the energy monitoring, a total of 902,20 KW was recorded, despite not being at full load, which does not exceed the contracted power of 1,400 KW.

Transformer 01 is using a power of 576 Kva, which represents approximately 58 % of its maximum capacity and a low power factor (090). Transformer No. 02 is currently operating at a load of 454 Kva, which represents 45.4 % of its maximum capacity, with energy losses due to a low power factor (0.84).

The ISO 50001 methodology allows the generation of energy indicators, such as kilowatt hours per unit produced, tons produced or costs per monthly billing. A decreasing value of the indicator (e.g. 0.664) suggests an efficient use of energy, while an increasing value (e.g. 1.403) indicates an increase in energy losses.

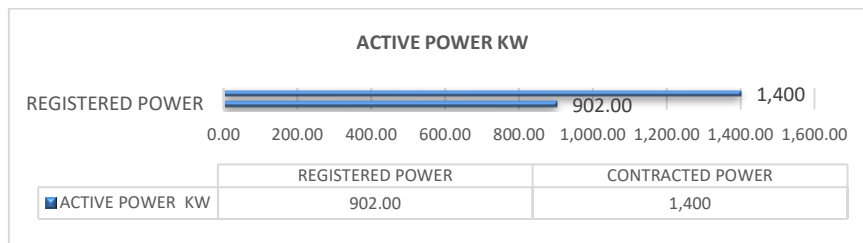


Figure 1: Contracted Power VS. Registered Power

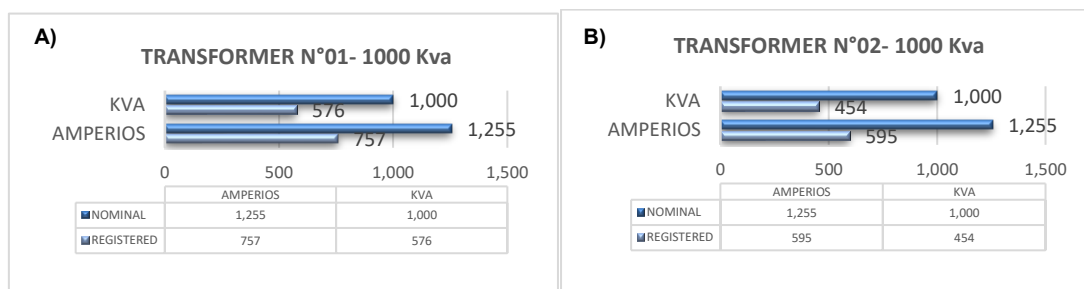


Figure 2 Transformer of the Electrical Sub station N° 01 and 02

Table 2. Energy consumption parameters recorded by scada

Item	Fac. Monthly	Kwh	Monthly Cost S/.	Indicator
1	Dec-23	251,696	249,817	0.993
2	Jan-24	184,561	258,885	1.403
3	Feb-24	318,831	300,750	0.943
4	Mar-24	318,001	297,251	0.935
5	Apr-24	449,177	360,064	0.802
6	May-24	389,129	323,654	0.832
7	Jun-24	401,375	334,859	0.834
8	Jul-24	393,234	261,255	0.664
9	Aug-24	362,769	288,129	0.794
10	Set-24	331,814	296,690	0.894
11	Oct-24	347,291	292,409	0.842
12	Nov-24	378,001	274,692	0.727

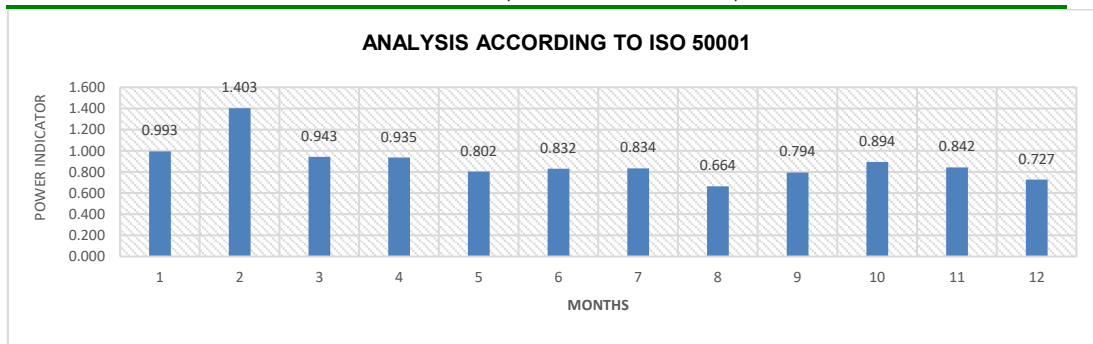


Figure 3 Energy indicator according to ISO 5001 standard

When the indicator registers low parameters, this reflects an efficient use of energy. To maintain this level of efficiency, it is essential to apply lean and continuous improvement methodologies. These methodologies allow us to identify and eliminate waste, optimize processes and ensure that energy resources are used optimally, thus contributing to sustainability and reducing operating costs.

Table 3. Energy consumption and carbon footprint parameters

Item	Fac. Monthly	Kwh	Carbon footprint
1	Dec-23	251,696	62,924.01
2	Jan-24	184,561	46,140.25
3	Feb-24	318,831	79,707.75
4	Mar-24	318,001	79,500.25
5	Apr-24	449,177	112,294.25
6	May-24	389,129	97,282.25
7	Jun-24	401,375	100,343.75
8	Jul-24	393,234	98,308.51
9	Aug-24	362,769	90,692.25
10	Set-24	331,814	82,953.51
11	Oct-24	347,291	86,822.75
12	Nov-24	378,001	94,500.25
	Total	4,125,879	1,031,469.78

To convert electricity consumption in kilowatt hours (kWh) to CO₂ emissions, a specific emission factor is used. According to regulations and carbon footprint calculators, it is established that 1 kWh of electricity consumed generates approximately 0.25 kg of CO₂ (HdC Calculation, 2005). In this process it was possible to validate the monthly average of 85,955 Tons of CO₂, as well as to register the annual emissions of 1,031,469.78 Tons of

CO₂. Electricity generation is one of the main sources of greenhouse gas (GHG) emissions. These gases include CO₂, CH₄, NO_x, among others

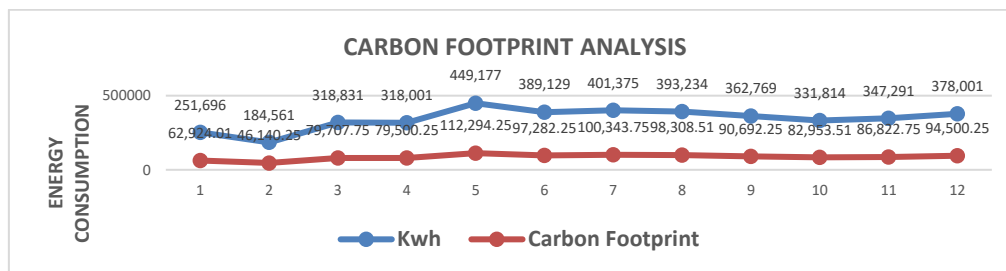


Figure 4 Analysis of Carbon Footprint and energy consumption.

5. Conclusions

The research has a significant positive contribution to the industry. Annual energy consumption was recorded at 4,125,879 kWh and annual CO₂ emissions were quantified at 1,031,469.78 tons. The implementation of the ISO 50001 standard has enabled us to reduce energy consumption and CO₂ emissions. By improving the power factor (3.87 %). Process improvement methodologies, oversized equipment (3.24 %), lean methodologies and continuous improvement (3.26 %) were applied. We also reduced our carbon footprint by 10.17 %. The adoption of ISO 50001 not only contributes to environmental sustainability, but also offers economic benefits by reducing operating costs in companies.

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